THINK BIG WE DO℠

Mechanical Engineering Capstone Design 2024-2025

Team 1 - Nuclear Power Solutions

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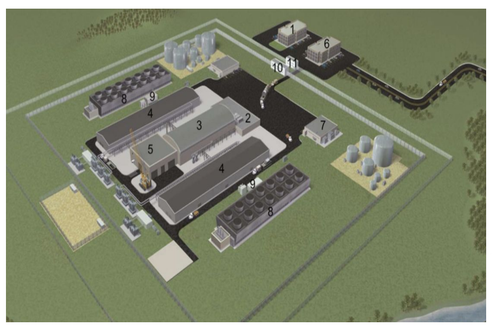
Where ingenuity and invention converge

Members: Owen Horiagon, James Russell, Thomas Scorpio, Nathan Segar
Advisors: Dr. Bahram Nassersharif, Mr. James L. Little

Abstract

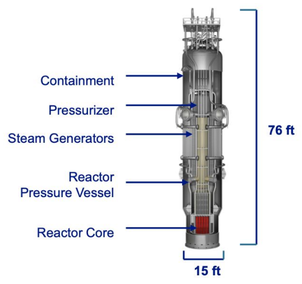
This project focuses on repurposing the retired Brayton Point coal plant into a next-generation clean energy facility by integrating a small modular reactor (SMR) to power a 250 MW AI data center. The purpose is to demonstrate a sustainable and technically sound solution that addresses both the rising demand for computational power and the need to decarbonize legacy infrastructure. Our objectives include designing and validating the NuScale SMR process, ensuring reliable integration with existing site assets, maintaining strict safety and licensing standards, and achieving zero net carbon emissions. The scope of work encompasses the complete system design, site retrofit planning, power distribution analysis, and evaluation of the data center's operational demands, paving the way for a scalable and job-generating energy transition model ine of this project is a proven design process of integrating a SMR based nuclear power plant into a retired coal site to power the grid and a AI data center.

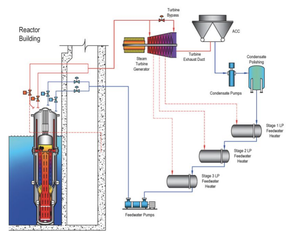
Integration of CPP



1. Admin Building
2. Annex Building
3. Reactor Building
4. Turbine Building
5. Radioactive Waste Building
6. Warehouse Building
7. Water Treatment Building
8. Cooling
9. Pump House
10. Security Building
11. Primary Access Control Building

NuScale SMR

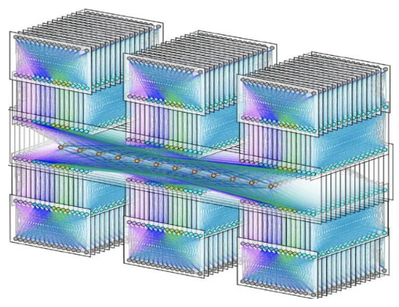




The NuScale Power Module is a small modular reactor developed by NuScale Power to provide scalable, carbon-free nuclear energy. Each module is a fully factory-fabricated pressurized water reactor. Designed with enhanced safety features, the NPM uses passive cooling systems that operate without the need for external power or human intervention, significantly reducing the risk of accidents. Its modular design allows for flexible deployment and scalability, making it ideal for a range of applications from remote locations to industrial and data center support.

AI Data Center

Our AI data center will require 250 MWe in order to function properly. Our data center will be constructed in Fall River Massachusetts, just over the bridge from our power plant at Brayton Point. This will bring high paying jobs to Fall River, with over 2,000 direct jobs and 5,000 temporary jobs until the project is complete and fully operational.



6 main categories of AI data center operation

Computing (60%)

GPUs: NVIDIA Blackwell (GB200)
- Performance: 20 Petaflops
- Memory: 141 GB of HBM3e
- Bandwidth: 8 Tb/s

CPUs: AMD EPYC (9005)
- Cores: 192 Zen 5 cores
- Threads: 384 threads/CPU
- Memory: 6 Tb of RAM/socket
- Interconnect: Infinity Fabric

Configuration: CPU:GPU ratio = 1:8
- GPUs: 10,000 NVIDIA GB200
- CPUs: 1,250 AMD EPYC 9005
- Consumption: 130-160 MWe

Cooling (25%)

Hybrid cooling is ideal for our AI data center because it balances efficiency, cost, and flexibility. It combines liquid cooling for GPU racks and air/RDHx for CPU/storage racks, achieving a PUE of 1.1-1.3. This saves ~$5-8M in capex versus full immersion, leverages Brayton Point's existing air-cooling infrastructure, and supports diverse workloads. With ~50-75 MW cooling power, it fits our 300 MWe budget, enables heat reuse for community benefits, and aligns with our replicable, sustainable design using nuclear power.

Networking (8%)

Interconnects: NVIDIA's Inifiband
- 800 Gb/s
- Spine leaf with 800 G switches

Bandwidth: 100-200 Tb/s aggregate BW
- For 1,250 Racks, 125-250 Pb/s
- Provides smooth, seamless communication from GPU to GPU

Power: Consumes 8% of the power
- 10 MWe required for networking
- Silicon photonics and optical switches cut energy use by 20-30%

Storage (5%)

NVMe SSD: All-flash arrays
- 100 Tb/drive, ~ 5-10 kWe
- 1 rack can store petabytes

Distributed Storage: Using Ceph system
- Ceph Storage Cluster on commodity servers
- Use SSDs for metadata and HDDs for bulk data

Capacity: 10-20 MWe
- Support 10-50 zettabytes
- Scalability allows growth thru 2030

Power (~ 308 MWe)

Power Distribution:
- High Amp Distribution >2500A
- 54V DC grids for some racks to minimize conversion loses

UPS Backup/SMR Integration:
- Allocating ~10 MWe for UPS loses
- VOYGR 12 pack allows scaling
- Connect to BPs 345 kV grid

Facility Design

Size: ~1,000,000 sq ft
- compute halls, cooling plants, and power systems.
- Repurpose BPs 300-acre site Build on 50-100 ac brownfield site

Modularity: Pod-based architecture
- 20 MW, 100 racks per pod
- Deployed to match demand.

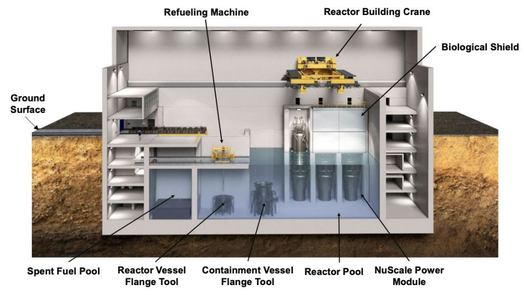
SMR Technical Data

Thermal Power	250 MWt
Electrical Power	77 MWe
System Pressure (Primary)	2000 psia
System Temperature (Primary)	598 F
Mass Flow (Primary)	4.66E6 1b./hr
Heat Removal	Natural Circulation
Fuel	Uranium Dioxide Pellet, 4.95% enriched
Weight	700 t.
Secondary Systems per Module	2 Steam Generators, 3 Feedwater Heaters with Pumps, 1 Turbine, 1 Condenser
System Pressure (Secondary)	475 psia
Steam Temperature	542 F
Steam Flow	8.14E5 lb/hr
Feedwater Temperature	200 F
Design Life	60 years
Refuel	18 months

NPP Functional Requirements

- Data center power usage: 250 MW
- Reactor*:* Nuscale US600 SMR (77MW)
- Scaled SMR max power output: 308 MW (excess power sold to grid and available as backup power for data center)
- NRC: license for Nuscale US600 power output
- Reactor safety: Passive cooling via natural circulation; no active pumps or external power required for shutdown
- Refuel length for one reactor*:* 30 days
- Plant availability factor (AF)*:* Greater than 92%
- Load rejection withstand percentage to handle data center trip: 100% (by using Nuscale design of steam bypass to integral heat sink)
- Auxiliary Power: 5–10 MWe from grid or on-site diesel generators for startup/shutdown.

Containment



The NuScale Power Module features a robust and safety-focused containment design. It is constructed below grade and housed within a stainless steel-lined pool, enhancing both structural integrity and radiation shielding. Classified as Seismic Category 1, the containment is built to withstand significant natural events. Its compact footprint allows for flexible site placement, while the incorporation of passive safety systems and multi-layer containment ensures protection without the need for active intervention. Each module operates independently, allowing for modular deployment and enhanced operational resilience.

Market Analysis

The coal-to-nuclear transition project at Brayton Point, leveraging NuScale's SMR technology, targets the surging demand for clean, reliable energy from AI data centers, a market projected to exceed $1 trillion by 2030. With data centers requiring 200-300 MW of 24/7 power, the proposed 300-308 MW SMR plant (6x reactors) offers a zero-emission solution, capitalizing on Brayton Point's existing grid and cooling infrastructure. The $3-4 billion project, fundable via private capital, DOE loans, and IRA incentives, aligns with Massachusetts' net-zero 2050 goals and ISO-NE's need for stable baseload power. It promises 300-400 construction jobs, 100-200 permanent roles, and $10M+ in annual tax revenue, boosting local economies.

Competitive advantages include NuScale's NRC-approved design, high reliability (>90% capacity factor), and scalability, outpacing retrofitting coal plants, which incurs $4B+ costs and energy losses from decarbonization efforts. Market risks include high upfront costs and potential regulatory delays, but hyperscaler demand (e.g., Microsoft) and government incentives mitigate these. By avoiding the trillions needed for historical carbon offsets, the project prioritizes pragmatic, forward-looking clean energy, positioning it as a leader in powering AI growth while displacing ~1M tons of CO_2 annually from fossil fuel alternatives.

Political Analysis

- Our major stakeholders would include
  - The federal, state and local government and regulatory agencies
  - Local residents in the surrounding area
  - Environmental and activist groups
  - Nuscale, National Grid, plant operators, construction firms, technology companies, data center operators and financial backers
- Our Project would be supported by
  - Local, state and federal government
  - Pro-nuclear residents
- Reasoning for support
  - Economic growth, revitalization and job creation
  - Cleaner energy that is very reliable
  - Greater investment and better training/education for residents

Conclusion and Acknowledgements

Our integrated SMR module design will provide a combined total of 308 MW to a data center and the grid. We have designed for excess capacity and sequential refueling/shutdown to ensure the data center is always being supplied with power. Safety of reactor design is verified by NRC licensing.t.Based our site analysis, engineering calculations, and information gathered and analysis completed on Nuscale SMR technology and data center schematics, a retired coal plant can be converted to a SMR based nuclear plant that supplies energy to both a 250 MW data center and the grid. **Next Steps and Further Work**: Project development, state licensing, acquiring data center customer, and a market and construction risk assessment.

Organized and taught by Professor B. Nassersharif, E-mail: bn@uri.edu, Phone: 401-874-9335